building blocks

What Do You Need to Know About Cold-Weather Concreting?

By Justin S. Pechar, P.E.

What is it?

The start of the cold-weather concreting season is defined by the American Concrete Institute (ACI) as a period when the average daily air temperature is less than 40°F for three consecutive days, and when the air temperature does not exceed 50°F for more than one-half of any day. Once it has started, the cold-weather concreting season extends until warmer weather arrives, usually late spring.

If concrete placed in cold weather is to achieve sufficient strength and durability, it needs to be properly produced, placed, and protected. Protection and curing should continue at sufficiently high temperatures long enough to produce the strength required for form removal and structural safety. *Figure 1* shows protection using a heated tent. The heated tent keeps the concrete warm and also protects it from the snow and wind. Placement of concrete during the early-fall and late-spring (periods usually not defined as cold weather) should include protection from freezing for at least the first 24 hours if frost or freezing temperatures are expected. If allowed to freeze, concrete can be permanently weakened.

Proper cold-weather concreting practices include:

- Heated concrete materials.
- Lower slump (less than 4 inches) concrete mixes for flatwork and pavements.
- Air-entrained concrete to avoid damage of concrete from freezing while concrete is saturated.
- Protection above 50°F if specified strength must be attained in a few days or weeks.
- Curing conditions that foster normal strength development without excessive heating. Lower temperature curing needs to be continued for longer periods.
- Protection to limit rapid temperature changes. (Large temperature differentials cause thermal stresses and cracking, particularly at lower strengths. Protection should be removed gradually.)
- Protection from freezing until the concrete has reached 500 psi compressive strength. Concrete can resist one freeze thaw cycle at a strength of 500 psi provided no external curing water is present on the surface.

Figure 1: Cold-weather concreting protection using heated tents

Temperature Control of Concrete

Temperature affects the rate at which cement hydration occurs; low temperatures retard concrete hardening and strength gain. Concrete must be placed and then maintained at temperatures recommended by ACI 306R (Cold Weather Concreting) to allow the best opportunity to achieve the specified strength.

The minimum concrete temperature is dependent on both air temperature and thickness of the section. For sections of moderate thickness (approximately 12 inches) and size, the concrete should be mixed at between 60°F to 70°F depending on air temperature and then maintained at a minimum temperature of 55°F. The maximum concrete temperature should not exceed the minimum concrete temperature by more than 20°F. Concrete temperatures should be measured at edges and corners to ensure they are being adequately maintained. Concrete strength should be verified by testing field-cured cylinders. It is not uncommon for concrete in the field to have a 25 percent reduction in strength gain in cold weather.

Preplanning Considerations

Figure 2: Insulating blankets for protection of concrete during cold weather

The overall costs of adequate protection for cold-weather concreting must be considered. The owner needs to evaluate the alternative of waiting for milder weather. All parties involved (contractor, concrete supplier, engineer, and owner) should meet prior to construction to define what cold-weather concreting methods will be used. Plans should be made well before cold weather is expected to occur, and protection for materials should be at the site ready for use. Considerations include:

- Use a concrete mix and cement type with a proven history of successful results in cold weather, especially for flatwork.
- Consider using a concrete mix design with a design compressive strength of no less than 3,500 psi. ACI 306R recommends not exposing saturated concrete to multiple freeze-thaw cycles before the concrete develops a compressive strength of 3,500 psi.
- For foundations and slabs, protect the subgrade; it should not be frozen nor allowed to freeze. These areas may need to be tented (see *Figure 1*) and heated for 12 hours or more prior to the pour. Forms, reinforcing steel, and embedded items should be free of snow and ice.
- Heat mixing water, aggregates, or both.
- Coordinate the length of curing time required with other construction activities. Extra protection materials, or means of heating, should be available in case of unexpected conditions.
- Use insulating blankets and/or forms like those shown in *Figure 2*.
- Determine methods of monitoring concrete temperatures or test field-cured cylinders, when specified.

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Acceleration of Strength Development

High strength at an early age is frequently desired during cold weather, to reduce the length of time that cold-weather protection is required. Methods include:

- Use of high, early-strength cements; ASTM C150, Type III or IIIA.
- Additional cement.
- Chemical accelerators.

Good results may also be achieved with the addition of an extra bag of cement for each cubic yard of concrete or with the use of high, early-strength cement. Engineers should also be aware that using fly ash in cold-weather concreting applications will delay strength gain and make the concrete more prone to freeze damage. The use of anti-freeze compounds to lower the freezing point of concrete should not be permitted because other properties of the concrete are often affected. Accelerators such as calcium chloride are also not recommended, especially as a substitute for proper curing and protection, because of the potential for corrosion of reinforcing. Noncorrosive accelerating admixtures are available; many are water-reducing, accelerating admixtures conforming to ASTM C 494, Type E. However, they should not be used indiscriminately in flatwork due to the increased potential for shrinkage.

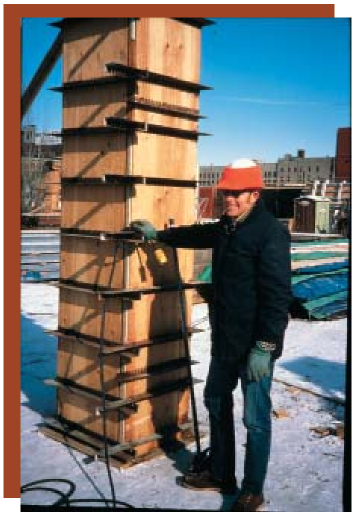

Figure 3: Insulated formwork for cold weather concrete protecion

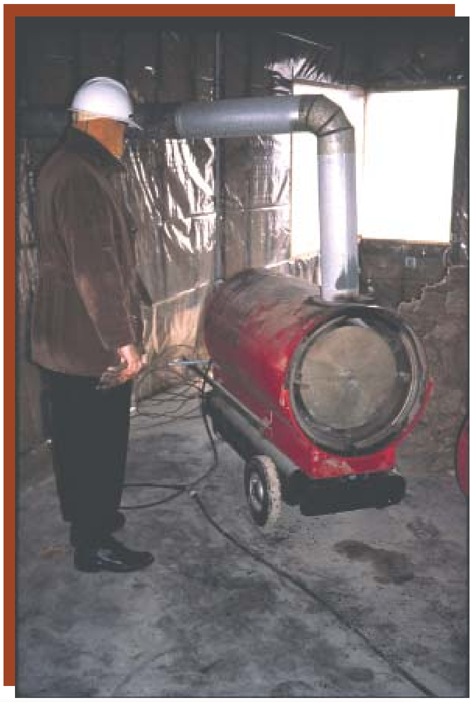

Figure 4: Cold-weather concreting protection with heated enclosures that are vented

Figures 2, 3 and 4 courtesy of Portland Cement Association

Curing and Protection

Concrete placed during cold weather should be maintained as close as possible to the necessary temperatures for the minimum length of time recommended by ACI 306 for different cements and service load categories. The criteria for the removal of forms and shores for structural concrete should be based on in-place strength testing or field-cured cylinders, rather than arbitrary times.

Concrete in forms or covered with insulation seldom loses enough moisture at 40°F to 55°F to impair curing. Greater amounts of insulation are required for concrete requiring longer curing periods, and at exposed concrete areas where heat loss is greater. Insulation should be kept in direct contact with the concrete. *Figure 3* shows an example of insulated formwork for a building column. The insulating material is located behind the plywood formwork. Protection should be removed in a manner to avoid abrupt temperature changes in the concrete; otherwise, thermal shock and cracking could result.

When heaters are used, they should be vented from the enclosure or tent as shown in *Figure 4*. Moist curing, with an external supply of moisture, or sheet curing is recommended to offset the drying effect of the heated enclosures. Sheet curing is usually recommended in cold weather. The author does not recommend the use of liquid membrane-forming compounds as a substitute for moist curing or sheet curing.

The ACI Committee Report 306R outlines cold-weather concrete techniques. Concrete must be mixed, placed, and cured at proper temperatures for the correct length of time to achieve the desired strength and surface durability. With the proper planning and procedures, concrete can be satisfactorily placed during cold weather.▪

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